The mass-interaction scheme as a musical language : the GENESIS environment

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Abstract

Musicians usually consider physical Modeling as a particularly interesting paradigm as for its phenomenological interests, but also as a particularly impracticable one. We face today a lack in musician-oriented environments for practicing modeling in the context of musical creation. The article introduces GENESIS, a graphical environment based on the CORDIS-ANIMA mass-interaction system. GEENSIS was conceived so as to help the user "think physical"; that is, to discover and experiment with new ways of creating music, in which physical modeling is the central activity. Examples of composer's works are discussed.

1. Introduction

For the last fifteen years, physical modeling (PM) has become one of the most promising paradigms in computer music. Both scientific publications – see [1] for a review – and musical works have proved its phenomenological interests, ie. the quality of the musical sounds it leads to. But, surprisingly, the practice of PM for music still hardly encounters an important success.

A few reasons can be discussed. First, historically, Computer Music has focused on the sound signal (which is analyzed, synthesized, processed, etc.). The diffusion of PM in the musical community requires a paradigm shift in the use of computer for creating music, which will take a long. Second, the design of a 'musical physical model' is often considered as requiring some scientific knowledge hardly possessed by musicians, and far from any musical concern. As a consequence, most of the environments designed for musicians tend to hide the PM scheme used to specify models. Some environments mainly propose only large building blocks ([2], Yamaha VL1...). Others tend to promote signal-based control parameters that are more usual to musicians (see [3] for example). Indeed, though PM is often considered as a new approach to sound synthesis which main interest is to empower musicians with better sounds, another approach is possible. Particularly, we consider that the future of PM in the context of musical creation calls for the search of radically different approaches to computer music, in which PM would be the central mean of the whole creation process.

This article introduces the GENESIS environment based on the CORDIS-ANIMA mass-interaction system [4] and dedicated to musicians. GENESIS was designed in order to experiment the validity of PM as a central activity over musical creation. The article first describes the CORDIS-ANIMA simulation engine we choose. The main features and ergonomic properties of the GENESIS workbench are then exposed. As a final step, examples and works by composers are discussed.

2. 1D Mass-Interaction Paradigm

Given the aims discussed above, the choice of a modeling scheme and a simulation technique is important. Today, different approaches to PM present different benefits [1]. Among them, the mass-interaction paradigm allows a highly modular process. Each of its basic modules has an easy to comprehend physical behavior. It enables an efficient and natural mental model of algorithms, which helps in reducing the gap between reality and "virtuality". Given these properties, the mass-interaction paradigm appears to be particularly interesting when the aim is to let a non-physicist musician create the entirety of his musical material, including modeling.

The GENESIS environment is thus based on the topological (or one-dimensional) CORDIS-ANIMA [4], mass-interaction system. A CORDIS-ANIMA model is a network of elementary modules of two kinds: mass-like elements <MAT>, and physical relations <LIA> which connect <MAT> to each others. In addition to the traditional linear modules (such as fixed-point, inertia, stiffness, damping, etc., called respectively SOL, MAS, RES, FRO within CORDIS-ANIMA...), two – and only two – non-linear interactions are used in GENESIS:

the BUT module, which models contact through a visco-elastic interaction conditioned to position.

the LNL (non-linear link) which groups together a non linear viscosity and a non-linear elasticity. A LNL is made of two point-by-point curves. The first defines the force to be applied according to the distance of the two connected masses. The second curve defines the force to be applied according to the relative velocities of the two masses. This non-linear interaction allows, for example, the modeling of plucking and bow/object interactions.

These 6 basic modules are the only basis of any model within GENESIS. Their functions and behaviors are all easy to conceptualize, which we consider as very important for enabling musicians with modeling.

In the topological version of CORDIS-ANIMA implemented in GENESIS, the mass-like elements move

and the forces are applied along a single axis. The use of such a 1D simulation space allows at the same time higher speed simulations, easier modeling and interesting sounds and models.

3. The GENESIS' "Lutherie" Workshop

3.1. The 'Lutherie' workbench - representation

GENESIS enables "direct manipulation" of the models that are graphically displayed. This lets users interact as directly as possible with modules and objects during modeling.

The graphical 2D representation we propose (figure 1) is a metaphor of an instrument-maker or "lutherie" workbench. The "lutherie" workspace can be as large as needed – let's say 1000 m2 for example – and each object may be composed of a large number of modules – more than 10 000 in some complex works.

On the workbench, shapes and colors are used to represent the module's category. Attention was given to the use of size, hue and intensity of color, in order to represent the value of the physical parameters, since they can vary over many powers of 10 while small variations may still be significant. The choices optimize the information users can easily acquire by looking at the workbench. Moreover, they no doubt help models be perceived as objects, and not only as mathematical or algorithmic constructions. They enhance the modeling process and encourage an intuitive way of thinking.

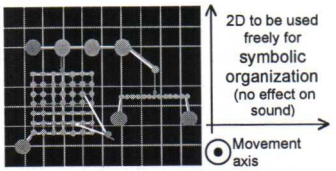

Figure 1: The "Lutherie" workbench metaphor.

Due to the use of the one dimensional mass-interaction scheme, masses move only on the axis perpendicular to the workbench. The position of the masses along the two axes of the workbench do not have any effect on the phenomena generated and can be assigned freely. Such a 'free' 2D workbench proved to be efficient for musicians, who use it in order to carry various symbolic information, depending on their needs. For example, a model's organization can evocate the real object modeled, underline a behavior of a specific part of an object, symbolize time from left to right, physically express some kind of partitioning, or allow some kind of a pictorial approach to modeling.

3.2. Basic editing features

Modularity is a key-word when using the mass-interaction modeling scheme: each elementary module is a very small but still physically significant grain of matter, and object shape and behavior emerge from built networks. As a basic philosophy, we aimed at letting the user operate at an elementary level and experiment with the behaviors of every category of module. Thus, GENESIS provides all the functionality necessary to specify the network of modules in terms of both structure and parameters (figure 2).

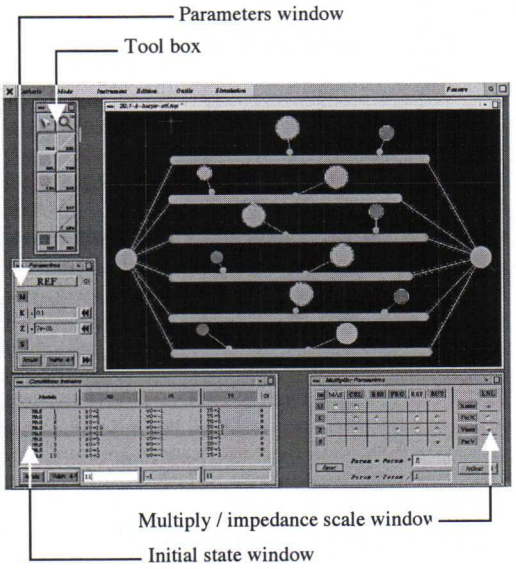

Figure 2: global view of the workbench

All the structural actions are handled in GENESIS through a toolbox. Users add or remove modules and connect or disconnect liaisons, as if they were dealing with real masses and liaisons. Direct manipulation is also rooted on a specific selection paradigm. Each module can be easily added to or subtracted from the selection, with different mechanisms: module selection, area selection, module category selection, criteria-based selection, set selection (see below), etc.

Physical parameter edition is mainly based on the homogeneous properties of matter. By selecting modules and provided they are homogeneous, the user is able to choose their parameters (inertia, damping stiffness...) among some 'preferred values' or to edit their precise numerical value. A multiply tool is also provided. It allows scaled modifications over selection. By applying the same factor to all the parameters, the selection's impedance can be changed: its intrinsic behavior is not modified but the way it interacts with other parts of the object is affected. Alternatively, by multiplying only the stiffness parameters, the user will affect the frequency properties of the selection.

A two-level editing tool is provided for editing the parameters of the non-linear LNL module, which are more complex. The first level displays the two shapes of the LNL but allows only modifying their amplitudes. Within the second, user can modify the shapes of the non-linearity, with both graphical and alphanumerical edition means (figure 3). LNL modules allow a

large diversity of non-linear interaction that can be physically consistent or not. The advanced editing window was thus designed in order to offer as much freedom as possible in the data specification. However, common LNL shapes are provided pre-built.

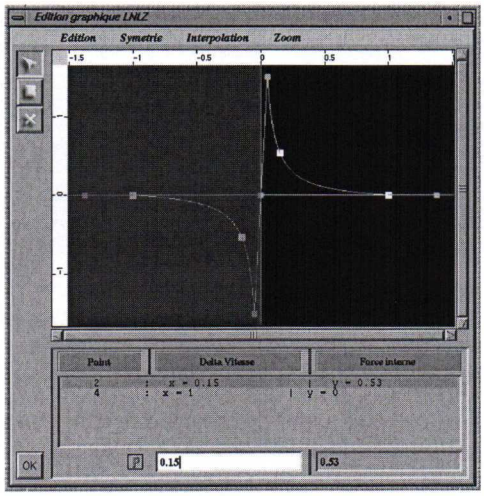

Figure 3: LNL Non-linearity edition tools.

3.3. Macro-modularity features

Modeling with the mass-interaction paradigm implies the use of a large number of elementary modules. Users exhibit a highly modular approach to modeling, establishing dependencies or hierarchies between sets of modules and parameters. This modular process is helped through various features in GENESIS.

The user can whenever he needs nominate the current selection as a 'selection set'. Sets are non-exclusive: a module can belong to more than one set. Sets are thus a powerful tool for specifying structural relationships between modules, whatever the reason for this relationship may be.

Basic physical parameters are not sufficient to summarize the properties of a model. To control certain behaviors, users often have to think in terms of dependencies between parameters of different modules, or even to define a new parameter space set of axes. The relation and meta-parameters tool allows objectifying these relations through a mathematical language. Then, users can either compute basic physical parameter from any meta-parameter or work at the basic physical parameter level.

3.4. Tools dealing with phenomena

Other tools aim at offering bridges between the CORDIS-ANIMA models and the properties of the phenomena to be generated. This is achieved by analyzing a GENESIS object in order to give information on the phenomena it may generate, or on the contrary by generating a model or its parameters according to a given set of desired behavior and/or phenomena.

3.4.1. Modal Analysis and Tuning

A 1D mass-interaction model with masses and spring-frictions is a linear model. GENESIS provides a modal analysis engine [5] that computes Eigen frequencies, damping times and shapes of the modes (Figure 7). When analyzed, it is possible to tune a given structure to a given frequency and damping time by computing the correct stiffness and viscosities over the structure.

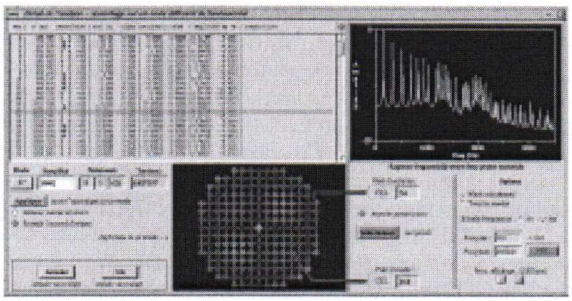

Figure 4: The modal analysis window.

3.4.2. Structure Generation

Structure generation tools aim at generating a CORDIS-ANIMA model whose behavior matches a given set of phenomenological data. This "reciprocal problem" is mathematically difficult to solve – it may have no solution, or an infinite number of solutions. The generation tool GENESIS currently proposes is able to generate an inhomogeneous cord-topology model that matches any desired mode list.

3.4.3. Scheduling of elementary gestures

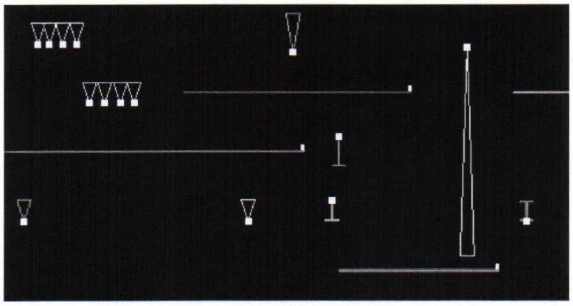

Figure 5:the scheduler for physical starters.

A basic initial state window allows specifying the positions and velocities of each mass along the movement axis. However, within GENESIS, initial conditions gain to be understood as very elementary "gesture inputs". For example, a MAT launched toward a sound object and connected with a BUT will strike the object after a given time. Within GENESIS, such a mass is called a starter. It stands for an elementary gesture that is applied on an object in order to start a musical event. A graphical scheduler helps in editing the initial state of such starters (figure 5).

Within the scheduler users can affect the initial state of a starter by controlling the intensity (size of the graphical signs) and occurrence date (the position of the sign along the X axis). Though it is basic at the moment, the scheduler appears to be an efficient tool for dealing more closely to sound events – as in a musical score – within the physically-based 'philosophy' GENESIS promotes.

3.5. GENESIS' Simulation Features

An experimental version of GENESIS supports real time with multiprocessor computers and gesture interaction through force-feedback device. However, the standard version is non real-time, which allows the computation of very large models.

Simulation is the main mean to validate models and/or understand their behavior. It is used frequently within GENESIS. Considerable effort was devoted to the design of the simulation window. Depending on the needs, it will display the sound signal - and eventually perform measurements on it -, the object's movements currently calculated (figure 6) or measurements made on the object.

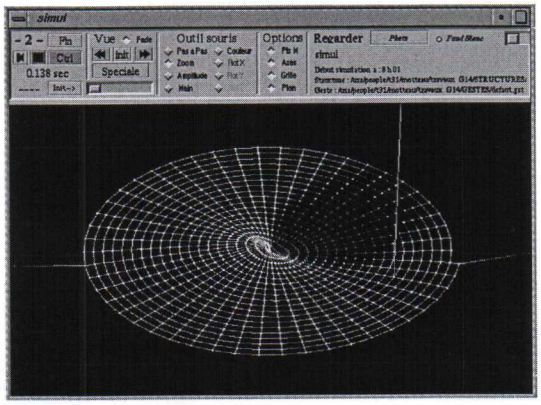

Figure 6: Graphical view during simulation.

3.6. Results and Conclusions

The design of Genesis has been made over many years in close collaboration with composers: Ludger Brumer, Hans-Peter Stubbe, Giuseppe Gavazza and Claude Cadoz, for example. GENESIS is today available within a growing network of users. Pedagogical work-shops are organized regularly.

As a result, GENESIS provides new proofs of the sound quality enabled by physical modeling (PM). Various musical pieces created using the software were awarded. However, more promising results were obtained.

Through GENESIS, PM stands as a mean for musical creation rather than only sound synthesis. Users often deal with large multi-scale models that mix high and low frequency objects connected to each other. These models stand for both sound objects and a representation of musical gestures (figure 7; see [6] for details). Such a process proved to be relevant for the synthesis of complex musical phrases rather than isolated sounds. It addresses, indeed, the musical composition level.

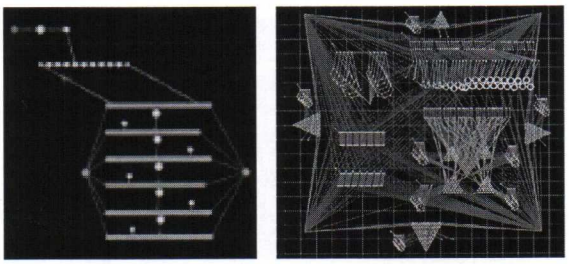

Figure 7: Complex musical structures. Right: a model by C. Cadoz, with more than 10000 modules, that inherently generate the 5min. musical piece "pico..TERA".

Thus, beyond their phenomenological interest, physically-based modules and models appear to be relevant as musical signs. Through GENESIS, masses and interactions are the basis of a new modular musical language. This language can be acquired and practiced by musicians themselves, by developing what could be called an intuitive physical thought. This physical approach to music creation, moreover, appears to be musically relevant and efficient to represent musical ideas. As evidence, the design and use of physical models needs a change in the mental approach to sounds and music. GENESIS helps users to accomplish this radical but promising paradigm shift.

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